ER 9-0994B

15 MAR 1957

The Honorable James E. Murray
Chairman
Committee on Interior and Insular Affairs
United States Senate
Washington 25, D. C.

Dear Mr. Chairman:

With reference to my letter of 5 March 1957, I am enclosing herewith three copies of a study entitled Titanium in the Soviet Bloc. I hope that you will find this study useful in your consideration of the subject.

We shall continue to forward new information as it becomes available.

Sincerely,

SIGNED

Allen W. Dulles
Director

Enclosures (3)

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TITANIUM

IN THE

SINO-SOVIET BLOC

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FOREWORD

Reflecting Soviet policy regarding all nonferrous metals, the USSR has released few data on titanium. In June 1947, the Council of Ministers of the USSR declared that information on reserves and extraction of all nonferrous metals was "a state secret, the divulgence of which is punishable by law." This policy actually had been effective since the mid-1930's. The result is that the USSR (and the European Satellites as well) has released no direct information on the status of the titanium industry in the Sino-Soviet Bloc. Only recently, in fact, has the USSR permitted publication of scientific and technical articles on titanium. The Soviet writers have carefully avoided reference to the quantities of titanium raw materials, concentrates, or metal produced; the location of plants; or the extent of application in the aircraft industry or in other military production.

Under these conditions, assessment of the current status of the Soviet titanium industry is most difficult. Although the estimates and conclusions presented in this memorandum are believed to be reasonable, they necessarily have been derived by inference.

CONTENTS

TITANIUM IN THE SINO-SOVIET BLOC

Summary and Conclusions

Production of titanium sponge in the Sino-Soviet Bloc in 1956 is estimated to have been between 3,000 and 5,000 metric tons,* which at the maximum was about one-third as much as was produced in the Free World and 40 percent as much as was produced in the U.S. For all practical purposes the Bloc production of titanium is confined to the USSR. Although East Germany, Hungary, Czechoslovakia, Poland, and Communist China are known to be interested in the development of titanium and have done experimental work, production has been limited to laboratory-scale quantities.

The USSR is the only country in the Sino-Soviet Bloc that has adequate natural resources for supporting the development of a large-scale titanium industry. Although Soviet resources of rutile are negligible, Soviet reserves of ilmenite and titaniferous magnetite, containing 10 to 15 percent titanium dioxide, are enormous. There are major deposits of ilmenite in the Ural Mountains and the Kola Peninsula.

Soviet scientific and technical books and articles disclose a high degree of interest in titanium. These sources also indicate that the USSR is acquiring the technical experience necessary to the development of an integrated titanium industry. Soviet scientists have been assisted greatly by the theoretical and engineering details of Free World research on and development of titanium and titanium base alloys. They are familiar, for example, with vacuum melting procedures and both magnesium and sodium reduction processes, and they understand the consumable electrode and double melting techniques. Published Soviet material indicates, however, that the titanium industry of the Bloc is from 2 to 4 years behind the U.S. industry.

Although the USSR has shown strong interest in all aspects of titanium and is carrying on a large research and development program, it does not appear to be trying to match the growth of titanium production and utilization in the U.S. Available evidence suggests that

*Tonnages throughout this memorandum are given in metric tons.

Soviet metallurgists hold some reservations regarding the necessity for titanium in aircraft. Comparison of titanium base alloys with special steels, on both a strength-to-weight basis and a cost basis, may be responsible, at least in part, for the "wait and see" attitude of the USSR.

The USSR also is alert to the nonmilitary application of titanium. It is unlikely, however, that the less strategic uses will be of sufficient importance to the Soviet planners to alter the normal course of events in budget allocations. It is to be expected, therefore, that more intensive Soviet efforts in the production, fabrication, and utilization of titanium will follow acceptance of the metal by designers of Soviet military equipment, particularly aircraft.

I. Introduction

The purpose of this memorandum is to assess the current status and future industrial potential of titanium* in the Sino-Soviet Bloc, especially in the USSR. Although numerous scientific and technical books and articles on titanium have been published in the Bloc, they indicate no spectacular advances in the knowledge of titanium metallurgy. These publications clearly indicate, however, that the USSR is well aware of the potential significance of the metal.

II. Titanium in the USSR

A. Development, Technology, and Production

1. Evidence of Interest

Soviet interest in titanium dates back at least 25 years. Production of high-titanium iron, ferrotitanium, and titanium pigments from domestic ilmenite** ores was the main objective. More recently, Soviet scientists have also published numerous books and articles indicating a substantial research program on both the physical metallurgy of titanium and on the various methods for producing the metal. In addition, the Sixth Five-Year Plan specifically states that by 1960 "prospected" titanium deposits must be increased 40 to 45 percent in comparison with deposits available at the beginning of the Plan period.

*The Titanium pigment and ferroalloy industries will be mentioned only as they affect the production of the metal and titanium base alloys.

**Ilmenite is described in Part II C, below.

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2. Sponge Production Processes

There is no indication that the USSR has developed processes for producing low Brinell hardness number (Bhn),* low-carbon titanium sponge, which in any way is comparable to that produced from magnesium or sodium reduction processes in common use in the Free World. Early Soviet efforts to produce metal by the hydride, iodide, and electrolytic processes apparently proved to be commercially impractical. It is believed that the USSR has adopted the Kroll-Wartman magnesium reduction process for producing ductile sponge, which is a process developed in the U.S.

3. Ingot Melting and Ingot Size

As in sponge production, scrutiny of available Soviet technical literature on methods and equipment for titanium ingot melting indicates no significant departures from Western practice. In fact, Soviet publications reveal that Free World methods for melting sponge and scrap into ingots are being checked in Soviet laboratories and probably are being adapted to Soviet needs. A recently published article in the Soviet press by the well-known Soviet metallurgist G. Mikhaylov traced the course of titanium development from ingot melting in a graphite crucible, then in copper-lined water-jacketed ones, and finally the switch from tungsten electrodes to consumable electrodes in vacuum-arc furnaces.** The only positive information on ingot size was a reference to a 25-kilogram (kg) ingot that was produced experimentally in the laboratories of the All-Union Scientific Research Institute for New Materials, which may be primarily responsible for titanium research and development. Mikhaylov stated that there was no interest in the small-size ingot, from which it can be inferred that production of "large ingots" has been mastered, at least in sufficient quantity to satisfy needs for experimentation. The source of the sponge is left in doubt, but it is presumably of domestic origin. Particular attention was also given to Soviet success in producing a consumable titanium electrode by pressing a combination of titanium shavings and titanium sponge. The largest consumable electrode produced thus far was indicated to be just over 3 inches in diameter, whereas electrodes up to 26 inches in diameter are being produced in the U.S.

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* Brinell hardness number 150 and lower, usually associated with commercially pure, ductile titanium sponge.

** Mikhaylov's account undoubtedly was based on published U.S. technology.

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4. <u>Fabrication Technology</u>

Although information on production of sponge and ingots has been published in the Soviet press, there is no evidence of serious Soviet efforts to develop the industrial technology of titanium fabrication or of activity comparable in any way to the intensive, industry-wide efforts of the U.S. in developing mechanical working, welding, heat treating, or other techniques. It appears, however, that attempts are being made to roll titanium on a mill scale and that the quality and quantity of available sponge and ingots justify fairly large-scale experiments. Mikhaylov mentioned the necessity of rolling "huge ingots" and implied that experience gained in rolling small ingots could be applied to the rolling of large ingots.

In view of the accessibility of most of the Free World's titanium technology, there is no reason to doubt that the USSR could produce and fabricate commercially pure titanium and titanium base alloys. At present, however, whether the USSR is in fact doing so is speculative; there is no confirmatory evidence to show that titanium base alloys of good properties and consistent quality are available in commercial tonnages. Quantity production and fabrication of titanium base alloys were developed in the U.S. only after many years of the most concentrated development campaign in metallurgical history.

5. <u>Physical Metallurgy and Alloy Development</u>

Recent Soviet reports of research on the physical metallurgy of titanium suggest that it is from 2 to 4 years behind that of the U.S. In 1955, a paper written by a competent Soviet authority disclosed that melting was done in graphite crucibles and that the resultant material contained 0.8 percent carbon. A technical journal published by the USSR in September 1955 contained the statement that hot mechanical working of industrial titanium containing even a considerable amount (0.8 percent) of carbon did not present particular difficulties. Free World experience has shown clearly that a carbon content of 0.8 percent is far in excess of maximum allowances for quality products and that the industrial use of induction melting is impracticable because of the high carbon pickup.*

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*Recent experiments on close control of melting time and temperature in induction melting in graphite have reduced contamination to a low (0.03 to 0.08 percent) figure. This work may lead to greater use of induction melting.

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B. Current Trends in Technology and Evidence of Production

Statements of Soviet scientists and metal technicians indicate that such titanium sponge as is being produced in the USSR is made by the Kroll-Wartman magnesium reduction process. Production of titanium tetrachloride, required for the Kroll-Wartman process, from local raw materials is feasible; and the chemistry and methods for producing and purifying tetrachloride have been widely publicized in the Soviet press. There is also evidence which indicates that in the early 1950's the USSR was experimenting with a sodium reduction process, but there is no information to indicate the outcome of those experiments.

There is little information on the quantities of titanium produced annually in the USSR, and Free World estimates of Soviet output have ranged from negligible to 95,000 tons per year.* On the basis of the qualitative information given in the numerous Soviet articles on titanium published in the Russian language, it can be inferred that titanium sponge probably is being produced domestically in sufficient quantities to sustain experimental production of ingots of comparatively small size (perhaps as large as 1,000 pounds). On an annual basis, this output in 1955 and perhaps even in 1956 probably was less than 5,000 tons and may very well have been only about 3,000 tons. If the USSR is indeed producing a significantly larger tonnage of titanium sponge than this, which is highly doubtful in view of Soviet published statements on titanium research and development, Soviet officials are being modest to a degree unparalleled in the history of industrial development in the USSR.

C. Raw Material Base

The abundant authentic information on the geology of the USSR indicates clearly that the nation has adequate natural resources to support a large-scale titanium industry. Although the USSR has only limited deposits of rutile, the only low-cost titanium mineral used for making titanium metal, it has extensive deposits of low-grade titanium-bearing ores. The main resources are the titaniferous magnetites in the Ilmen Mountains, a branch of the Urals. It is from these mountains that the mineral "ilmenite" received its name. These deposits were reported in 1938 to constitute a reserve of 400 million tons of ore. The ores, which contain 14 percent titanium dioxide, 54 percent iron, and 0.6 percent vanadium pentoxide, are amenable to magnetic separation. The concentrate so obtained contains 42 percent titanium dioxide and 37 percent iron.

* The latter figure, widely circulated in the Free World press in late 1955 and early 1956, originated with a U.S. newsman who misinterpreted an estimate of titanium ore reserves in the USSR obtained from an unidentified source in the U.S. Government.

There are other important deposits of ilmenite on the Kola Peninsula. Titanium dioxide is contained in the apatite* ores of the Kola Peninsula, which are being mined by the Kirovsk Apatite Combine, a producer of mineral fertilizer.

Although the USSR has an abundance of titanium-bearing ores, most of them are low in grade, by Free World standards, and require beneficiation. The resulting concentrates are satisfactory for the production of ferrotitanium, titanium-rich slags (72 to 75 percent titanium dioxide), and pigments, but they are not particularly desirable for economic manufacture of titanium tetrachloride, the industrial chemical source of titanium which is vital to both the magnesium and the sodium reduction processes. These processes are now the only ones that yield a commercially satisfactory ductile titanium sponge. The most advantageous and economic raw material for the production of titanium tetrachloride is rutile, which is reported to occur in the USSR only in the remote Kyzyl Kum area.

Other raw materials needed in the Kroll-Wartman process (or its sodium variation) include, of course, magnesium or sodium reductants, chlorine for the production of titanium tetrachloride, inert gases such as helium and argon, carbon, electric energy, and minor quantities of a few common materials. All of these are available in adequate supply in the USSR.

D. Utilization

1. Aircraft Industry

Recently produced Soviet aircraft and parts of such aircraft have not been available for examination in the U.S. or elsewhere in the Free World, and concrete evidence of Soviet application of titanium in aircraft is not available. Although the extent to which Soviet aircraft contain titanium is uncertain, there is no doubt that Soviet aircraft engine designers have carefully considered using titanium in gas turbine engine compressor discs and blades and are well aware of titanium's potentialities in other applications. For example, they are known to have compared the properties of a titanium-aluminum-chromium alloy, corresponding to one developed by the Mallory-Sharron Titanium Corporation, with other light-metal alloys and steel. After comparing the weight savings and relative costs of titanium and steel, Soviet officials stated that "as titanium alloys are mastered and they are more extensively produced, we can expect a reduction in cost, both of the material itself and of parts made from it."

*Calcium fluorophosphate.

2. Civilian Applications

No quantitative or qualitative data on civilian applications of titanium and titanium base alloys in the USSR are now available. Several popular articles in the Soviet press have stressed the value of titanium in such nonmilitary applications as corrosion-resistant pipe and pipe fittings, fasteners, and electronics. Such limited information does not justify estimates of the quantities so used.

III. Titanium in the European Satellites and Communist China

A. Hungary

Hungary has shown considerable interest in titanium, particularly in recent years. Although the Hungarians have published several scholarly reports on titanium technology, the reports are based exclusively on Free World developments.

Having no workable deposits of titanium ore, Hungary has confined laboratory experimental work primarily to efforts to extract the metal from the "red mud" produced as a residue in the manufacture of alumina, one of Hungary's major industries. Hungarian red mud residue may contain 5 to 6 percent titanium dioxide and other values in iron, vanadium, alumina, and caustic soda. On further chemical processing, and finally thermal reduction of the iron to pig, a titanium slag containing about 22 percent titanium dioxide can be produced, and then titanium can be extracted by chemical means. The economy of such involved processing of a low-grade residue depends on the recovery of not only the titanium, iron, and vanadium but also a good part of the alumina and chemicals contained in the red mud. A recent Budapest press report claimed that experimental production of titanium would be started by a Hungarian alumina plant and that large-scale production of titanium would be attained by the end of the Second Five-Year Plan (1956-60). If this is true, Hungary could, perhaps, supply domestic needs.

B. East Germany

In East Germany, research on various phases of titanium production processes, on bench and small pilot-plant scales, has been carried on intermittently since World War II at Elektrochemisches Kombinat Bitter feld (EKB) and other East German research centers. The early work on titanium reportedly was on the Soviet account.

Work in 1955, especially at EKB, has sought methods for recovering titanium from low-grade titanium-bearing materials from domestic sources, such as brown coal ashes, Baltic Sea black sands, and red mud residues from alumina plants. Experiments on the production of titanium sponge using a modified Kroll process were under way in 1955. In this process, titanium chloride was being reduced with magnesium <u>in vacuo</u>, i.e., without using a noble gas atmosphere.

Like Hungary, East Germany has no favorable natural-ore source of titanium and is unlikely to develop a sizable industry based on domestic materials. Any country with a titanium pigment industry, of course, could use high-priced* anatase (titanium-dioxide pigment) as a source. Occasional reports of industrial-scale production of titanium from this material in East Germany cannot be verified.

C. <u>Other European Satellites and Communist China</u>

Czechoslovakia, Poland, and Communist China are known to be interested in titanium, and on several occasions officials of those countries have referred to titanium as "the metal of the future." The scarcity of raw material resources in these countries indicates that in none of them has titanium production gone beyond laboratory experimental work.

Little is known about efforts in other European Satellites, but it is fairly safe to assume that research on some phases of titanium production and fabrication is in progress in most of them.

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*The U.S. price of anatase per pound of titanium content is about 40 cents, compared with ilmenite concentrate at 3 cents and titanium slag at 4 cents.

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MEMORANDUM FOR: The Director

The attached study is a de-classified version of a classified paper produced for the Director of ODM in January of this year.

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Legislative Counsel

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